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Project Acronym: DI-PHDICTKES

Project title:

The development and implementation of PhD Curricula in ICT for Kosovo Education System

WP 2.3.2

Syllabuses for the courses of the PhD program in ICT

Programme: Erasmus KA 2

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Duration: 36 months

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In the following, we present the content of the short syllabuses for all three categories of courses that include: (1) General courses, (2) Professional courses and (3) Soft skills courses. The main principles used for designing learning outcomes in individual course syllabuses are the guidelines of the Bloom's Taxonomy for PhD studies. In addition, all presented courses in the curricula encompass a general list of topics for a niche computing discipline, whereas more specialized and advanced topics could be included by individual institutions based on the expertise of their staff members.

General courses

1. Science & Research methods in ICT (7ECTS)
2. Ethics and research integrity (3ECTS)

Science & Research methods in ICT (7ECTS)

The purpose of this core course is to link doctoral students and faculty on research topics in Information and Communication Technology through assignments, presentations and a final term paper/project with their chosen faculty mentor. Topics covered include but are not limited to the nature of research in information technology; research problem selection, development, and presentation with special emphasis on the doctoral dissertation; dissertation process; development and crafting of papers for journals; collaboration on research projects; and the review process for journal papers. Upon completion of this course, students should be able to: 1) evaluate knowledge of research in information technology, including its reference disciplines and 2) plan a proposal for a significant and interesting research problem as a potential dissertation topic. Their understanding of the field and ability to identify research problems in any of these areas will be examined in their Part 1 comprehensive exam.

Prerequisite(s): Admission to PhD program in Information Technology or permission of instructor. Not open to non-degree graduate students.

Ethics and research integrity (3ECTS)

The purpose of this course aims to strengthen a culture of research integrity by presenting the various issues involved and promoting a critical approach. It is essential for every researcher to understand how to conduct their research ethically, and with integrity. Upon completion of this course, students should be able to: 1) appraise the importance of applying ethical principles during the conduct of research, 2) prioritize the basic framework of the guidelines, rules and regulations that exist to manage ethical issues that arise in research, 3) value the importance of carrying out research that is reproducible and reliable and to appreciate the many factors that go into conducting rigorous research.

Prerequisite(s): No prerequisites.

Soft skills courses

1. Personality & Self management (3ECTS)
2. Innovation, Entrepreneurship & Startups (3ECTS)
3. Leadership & Responsibility (3ECTS)
4. Business & Industry (3ECTS)
5. Communication (Transferable skills) & Methodological Competence (3ECTS)

Personality & Self management (3ECTS)

The purpose of this course is to teach students about techniques related to personality and self management, which will help them be better prepared to tackle struggles that might arise during their PhD study period. The specific topics include: mindfulness and embodiment, stress release for the scientific minded people, self care, productivity, emotional intelligence, personal and social competence, mental strength, the art of self-motivation, approaching the new work environment, communication, clarity in expression, voice, speaking, body language and shaping change competently. Upon completion of this course, the students should be able to: 1) Evaluate isolating situations and manage them with confidence, 2) Plan stressful situations competently and appropriately, 3) Appraise conflicting situations that might arise with supervisors and peers and deal with them using appropriate voicing and speaking techniques, 4) Plan the individual tasks optimally, 5) Judge the importance of work and life balance, 6) Prioritize the personal support and act to seek institutional support when needed, 7) Develop an understanding to tackle the concerns about the career after completing the PhD, etc.

Prerequisite(s): None.

Innovation, Entrepreneurship & Startups (3ECTS)

The purpose of this course is to teach students about the concepts of innovation, entrepreneurship & startups, with the goal of equipping them with the skills they need to transfer their research achievements into an innovation for the good of the society. Topics covered include: the concepts of innovation/entrepreneurship/startups, transforming PhD results into an innovation, activation of entrepreneurial mindset, communication skills for doctoral students, entrepreneurial leadership, self-empowerment. Upon completion of this course, the students should be able to: 1) Design analytical evaluation for transforming research artifacts into an innovation, 2) Demonstrate creativity, originality and self initiative for entrepreneurship, 3) Value clear communication (pitching) of complex research results (i.e. prototypes) to the stakeholders (e.g., investors, public organisations, non-governmental organisations, etc.), 4) Judge when applying reasoning, problem solving and ideation techniques, and 5) Perform systematic analysis and evaluation for diverse startup opportunities.

Prerequisite(s): None.

Leadership & Responsibility (3ECTS)

The purpose of this course is to teach the students about the role of a leader in a given institution/company and the associated rights and responsibilities. The topics covered in this course include: leadership basics; coaching skills for teaching, leaders for research and development; vision about the future; basic concepts of business; basics in business administration, finance and controlling; agile leadership; and decision making. Upon completion of this course, the students should be able to: 1) Judge the importance of the integrity and empathy of a leader 2) Judge appropriately the situations when to delegate tasks to subordinates, 3)

Demonstrate effective communication skills, 4) Appraise the importance of showing gratitude towards the subordinates, 5) Value basic knowledge of business administration.

Prerequisite(s): None.

Business & Industry (3ECTS)

The purpose of this course is to prepare the students for their period after the PhD studies, specifically for teaching them about the modalities for entering the domain of business and industry. The specific topics to be covered include: job application strategies for doctoral candidates, collaborative negotiation, essential skills for a career in industry, job application training for doctoral candidates (cover letter, résumé and interview), personal branding, legal issues about jobs in ICT, basics of the labor law, and designing the personal competence profile (identifying strengths and using them in a targeted manner). Upon completion of this course, the students should be able to: 1) Make strategic planning for application in the job industry 2) Develop an effective salary negotiation mechanism, 3) Value the most essential skills for a job in the ICT industry, 4) Create the job applications material (i.e cover letter, CV, web platforms for the personal profile (e.g, LinkedIn, GitHub, LeetCode, Kaggle, etc.)) that appropriately outline the key strengths of the candidate, 5) Evaluate the main points related to the applicable labor laws and specific laws for employment in the sector of ICT industry, etc.

Prerequisite(s): None.

Communication (Transferable skills) & Methodological Competence (3ECTS)

The purpose of this course is to teach the students about the main techniques for effective communication skills, as well as the methodological and transferable competencies. The main topics to be taught within this course include: communication strategies for knowledge delivery, scientific presentations, presenting research results in conferences and poster sessions, agile work and agile mindset, running successful meetings, preparation for the doctoral defence, scientific paper writing, planning and organizing the components of a presentation, team work, managing difficult/conflicting communications, visual communication in science, argumentation in scientific writing, project and time management, reflection and optimisation of the doctoral process, and good practices and guides in the scientific daily work. Upon completion of this course, the students should be able to: 1) Asses tools and techniques for an effective communication, 2) Evaluate the best techniques for answering questions and giving feedback, 3) Value the importance of body language in communication, 4) Exhibit empathy towards team members, 5) Demonstrate clarity and enthusiasm in research topic presentations, and 6) Compose an effective networking strategy with the peers.

Prerequisite(s): None.

Professional courses

Computer science

1. Intelligent Systems (AI) (7ECTS)
2. Graphics and Visualization (7ECTS)
3. Operating Systems (7ECTS)
4. Data Structures, Algorithms and Complexity (7ECTS)
5. Programming Languages (7ECTS)

Intelligent Systems (AI) (7ECTS)

The purpose of this course is to introduce main concepts in artificial intelligence such as: heuristic and algorithmic methods, problems solving, game playing, decision making, pattern recognition, adaptive learning, etc. Moreover, the course intends to provide broad perspective on artificial intelligence covering (i) classical approaches of search and planning useful for robotics, (ii) integer programming and continuous optimization that form the bedrock for many AI algorithms, (iii) modern machine learning techniques including deep learning that power most recent AI applications, (iv) game theory and social choice that capture interactions between multiple agents, and (v) issues of bias and unfairness in AI. In addition to understanding the theoretical foundations, also study of the modern algorithms in the research literature will be studied. Upon the completion of the course, students should be able to: 1) Judge classical approaches for search and planning, 2) Prioritize modern learning techniques and 3) Plan interaction choices of interactions between agents.

Prerequisite(s): Previous programming experience and background knowledge on Computer Science.

Graphics and Visualization (7ECTS)

The purpose of this course is to introduce more advanced topics on graphics and visualization such as: geometric models and their simplification, modeling with parametric curves and surfaces, geometry culling, illumination models and ambient occlusion in 3D and in screen space, texture mapping, ray tracing, animation techniques, visualization principle, visualization algorithms, virtual and augmented reality and other topics. Upon the completion of the course, students should be able to: 1) Value more advanced graphics and visualization principles and algorithms, 2) Design graphics and visualization programming through practical assignments, and 3) Develop advanced principles and algorithms in computer graphics and visualization. The students will realise the potential use of the above and possess the basis for performing research or pursuing commercial applications in the field.

Prerequisite(s): Previous knowledge on programming and visual computing fundamentals or other relevant courses.

Operating Systems (7ECTS)

The purpose of this course is for students to understand the state of the art in operating systems, to understand how to engage in systems research and to investigate new ideas in systems. The candidate will acquire knowledge of more advanced topics in operating systems, which will enhance their skills in the field of operating systems research. Instructor and the candidate will discuss different components of the research through a number of latest research papers and the candidate will work on a project component

based on those papers. Some papers that will be discussed will introduce the candidate to some of the basic principles of operating systems and some other papers will discuss more recent work and state of the art. Upon completion of this course, students should be able to: 1) Value advanced principles in the field, 2) Judge state of the art in the field and 3) Compose new interesting topics of research in the field.

Prerequisite(s): Previous knowledge in computer architecture and familiarity with operating systems concepts.

Data Structures, Algorithms and Complexity (7ECTS)

The purpose of this course is to get students acquainted with a variety of algorithm types, the organization and structuring of the data and as well as the computational complexity. Students will explore different kinds of algorithms and their performance as well as issues of implementation. Furthermore, related to the performance will also be the organization and structuring of the data but also limits of efficient computation.. Upon completion of this course, students should be able to: 1) Judge principles of algorithms, data structures and computational complexity, 2) Value state of the art related to algorithms, data structures and computational complexity, and 3) Use gained knowledge to develop new interesting topics of research related to algorithms, data structures and computational complexity.

Prerequisite(s): Previous knowledge on programming, algorithm basics, data structure design and analysis.

Programming Languages (7ECTS)

The purpose of this course is to cover advanced topics in programming language design, both in implementation and theory. Those topics include, but not limited to, structural systems design, dependent types, typed assembly languages, logical relations, operational reasoning, module systems, etc. Upon completion of this course, students should be able to: 1) Evaluate advanced topics discussed with the lecturer, 2) Plan reviews on chosen topics with the lecturer, and 3) Criticize the merits of the papers and make reviews on those papers.

Prerequisite(s): Previous knowledge on programming languages and use of a programming language.

Computer engineering

1. Architecture and Organization (7ECTS)
2. Parallel and Distributed Computing (7ECTS)
3. Embedded Systems (7ECTS)
4. Internet of Things (7ECTS)
5. Digital Design (7ECTS)
6. Circuits and Electronics (7ECTS)
7. Signal Processing (7ECTS)

Architecture and Organization (7ECTS)

The purpose of this course is to contain systematic material for students to get profound knowledge in the area of computer organization and architecture. The topics included in this course are: Measuring hardware solutions performance; Processor organization; Distributed systems architecture; Multi/Many-core; Processor organization; Memory system organization & architecture; Computer arithmetic; Input/Output interfacing and communication architectures; and Peripheral subsystems. Upon completion of this course, students should be able to: 1) Evaluate the design of computer hardware components, 2) Integrate hardware components to provide complete hardware systems with reliable and efficient functionality, 3) Simulate and evaluate the performance of parallel and sequential hardware solutions, 4) Value the tradeoffs involved in designing complex hardware systems in respect to the design of memory and arithmetical units as well as evaluation of diverse metrics about the system performance

Prerequisite(s): Knowledge in digital design and basic knowledge in programming..

Parallel and Distributed Computing (7ECTS)

The purpose of this course is to instruct the students to learn widely about parallel and distributed computing techniques. The main topics in this course are: Threaded applications; GPU parallel programming; Datacenter-scale distributed methods (e.g., MapReduce); Distributed graph algorithms; and Types of hardware architectures; Blockchain or Distributed Ledger. Upon completion of this course, students should be able to: 1) Design scalable parallel algorithms for high performance computing, 2) Judge distributed solutions that use task-based decomposition or data-parallel decomposition, 3) Write concurrent programs by considering actors and/or reactive processes, deadlocks, and properly synchronized queues, 4) Create test plans to reveal concurrent programming errors, 5) Make computational experiments and identify independent tasks that might be parallelized, 6) Design divide and conquer algorithms with parallelized implementation of tasks.

Prerequisite(s): Previous knowledge in the fields of programming, computer architecture and operating systems.

Embedded Systems (7ECTS)

The purpose of this course is to teach students about the core elements of the embedded systems and their integration into a computing system. The list of topics included in this course are: Parallel/serial I/O; Synchronous/asynchronous I/O; Interrupts and timing; Data acquisition & sensors; Embedded systems characteristics; Low-power operation. Upon completion of this course, the students should be able to: 1) Design and implement advanced I/O techniques, 2) Evaluate synchronous and asynchronous as well as serial/parallel I/O solutions, 3) Apprize interrupts and timing implementation strategies, 4) Design and

implement embedded systems in electronic and non-electronic devices, including sensor feedback, low-power operation, and device mobility.

Prerequisite(s): Previous knowledge in a hardware-level programming language, digital design and circuits & electronics.

Internet of Things (7ECTS)

The purpose of this course is to teach students about the modalities for connecting different physical objects into a common network by taking advantage of the latest developments in embedded systems, sensors, cloud computing softwares and other technologies that enable exchange of data between various devices over the internet. The main topics of this course include: Microcontroller boards/microprocessors (e.g. Arduino, Raspberry Pi, etc.) environments; Sensor & Actuators; IoT Networking; IoT protocols; and Cloud Platforms for IoT. Upon completion of this course, students should be able to: 1) Design systems of interconnections between digital technologies and physical objects that possess computing properties, 2) Design systems where physical objects communicate their states via centralized data communication mechanisms, 3) Create systems that enable coordinated data-driven actions by using high-performance computing devices and Big Data analytics softwares, 4) Develop computing systems by considering security and privacy issues and the impact of solutions on citizens and society.

Prerequisite(s): Previous knowledge in programming, cloud computing and embedded systems.

Digital Design (7ECTS)

The purpose of this course is to teach students about digital design concepts and the underlying techniques for optimal circuits analysis and synthesis. The topics taught in this course are: Tools & standards for digital design; Numbering systems; Data encoding; Boolean algebra; Digital logic, Combinational & sequential circuits; Control & datapaths; Programmable logic; System constraints; Fault models & testing. Upon completion of this course, students should be able to: 1) Design digital circuits (combinational & sequential) for various processor operations, 2) Evaluate appropriateness of tools for digital design, 3) Create control and datapath circuits using programmable logic, 4) Judge relevant system design constraints and testability concerns.

Prerequisite(s): Previous basic knowledge in mathematical logic and programming.

Circuits and Electronics (7ECTS)

The purpose of this course is to teach students about circuits and electronics engineering and the related hardware elements. List of topics taught include: Tools & standards for circuits and electronics; Electrical quantities, elements & circuits; Electronic materials & devices; MOS transistors; and Data storage cells. Upon completion of this course, students should be able to: 1) Evaluate and design circuits using electronic devices, 2) Innovate new electronic systems (chips) and build upon the existing ones, 3) Create new functions on varying levels of complexity by considering the tradeoffs involved, 4) Manage the process of the design of electronic boards, 5) Develop a test strategy for error detection and correction.

Prerequisite(s): Knowledge in digital design and linear algebra.

Signal Processing (7ECTS)

The purpose of this course is to teach students about the state of the art techniques for signal processing and the relevant tools, standards and the associated constraints. The main topics to be taught in this course include: Transform analysis; Frequency response; Sampling & aliasing; Spectra; Relevant tools for signal processing and the underlying standards & constraints; Convolution; Window functions; Multimedia processing; Control systems. Upon completion of this course, the students should be able to: 1) Design signal processing systems, 2) Apply the knowledge in sampling and quantization to bridge the analog and digital domains, 3) Evaluate signal processing challenges (e.g., detection, denoising, interference removal), 4) Select and implement appropriate algorithmic solutions including non-recursive and recursive filters, time frequency transformations, and window functions, 5) Apply signal processing knowledge in one or more interdisciplinary fields such as: cyber-physical systems, data communication, medical imaging, etc.

Prerequisite(s): Knowledge in linear algebra and calculus.

Software engineering

1. Requirements Analysis and Specification (7ECTS)
2. Software Quality, Verification and Validation (7ECTS)
3. Software Process (7ECTS)
4. Software Modeling and Analysis (7ECTS)
5. Software Design (7ECTS)
6. User Experience Design (7ECTS)

Requirements Analysis and Specification (7ECTS)

The purpose of this course is to teach students about the foundations and the state of the art mechanisms for requirements analysis and specification. The main chapters included in this course are: Requirement analysis; Requirement management; Requirement modeling; Business modeling; Modeling exercises; Requirement elicitation; Analysis and visualization of business strategy; Writing strategy map; Requirements triage; and Case studies. Upon completion of this course, students should be able to: 1) Identify and document system requirements, 2) Evaluate state of the art requirements elicitation technique in work sessions with stakeholders, 3) Develop facilitative skills for team leading and contribution to the team work, 4) Demonstrate appropriate written communication knowledge and skills, 5) Score system analysis and design knowledge and understanding, 6) Demonstrate capability of evaluating requirements analysis and specification and analyzing collaboration and teamwork.

Prerequisite(s): Previous basic knowledge in one or more fields of computing (e.g. computer science, computer engineering, information technology, etc.).

Software Quality, Verification and Validation (7ECTS)

The purpose of this course is to teach students about the techniques for software testing along with all associated testing artifacts. The topics to be covered in this course include: Review of software engineering methods and challenges; The role of verification and validation; The economics of verification and validation; Software reviews and inspections; Conducting reviews and inspections; Software quality metrics; Review of software configuration management; Software testing overview; Functional & Structural testing; Integration and system testing; Object-oriented testing; Software validation metrics; Assessing and improving the validation process; Assessing software quality; and Improving the development process. Upon completion of this course, students should be able to: 1) Design test cases for comprehensive code coverage and structured system testing, 2) Prioritise test cases based on feature importance and level of criticality, 3) Grade code quality based on understandability, cleanness and applicability of the respective state of the art standards, 4) Value the importance of unit, integration and system testing, 5) Collaborate with peers in inventing new test approaches.

Prerequisite(s): Previous knowledge in software engineering methods and programming.

Software Process (7ECTS)

The purpose of this course is to teach students about the foundations in software processes and the related state of the art particularites in both scientific and industry domains. The topics covered in this course comprise: Process Models and Solution Life Cycle Phases; Traditional Life Cycle Models; Alternative Techniques; Agile Software Engineering Process Models; Roles and Types of Standards; ISO 12207: Life Cycle Standard; IEEE Standards for Software Engineering Processes. Upon completion of this course,

students should be able to: 1) Engage with team members to translate software development processes into individual areas of responsibility, 2) Value the importance of the commitment and performance of individual team members upon their assigned areas of responsibility, 3) Measure the impact of software processes into the software development life cycle using appropriate tools and methodologies, 4) Propose and justify new software lifecycle process improvements based on team capacity, project progress data, and quality analysis.

Prerequisite(s): Previous knowledge in programming and project management.

Software Modeling and Analysis (7ECTS)

The purpose of this course is to teach students about the techniques in software modeling and analysis that are applicable in model-based system engineering. The list of topics covered in this course are: Creating Requirements; Modeling, Analysis, and Management; Define the System Context and Boundary; Define Interfaces and External Interface Elements; Define the System Behavior; Simulating Software Systems; Failure Modes and Effect Analysis; Verification Requirements and Test Plans; Upon completion of this course, students should be able to: 1) Design models for system engineering, 2) Develop requirements, architectures, systems behaviours, specifications, verifications and test plans, 3) Analyse and make critical reflections on the diagrams of an engineered system, 4) Develop simulation models that represent the behavior and performance of software systems, 5) Perform system analysis using model-based system engineering approaches.

Prerequisite(s): Previous knowledge in UML diagrams.

Software Design (7ECTS)

The purpose of this course is to teach students about software design techniques and the related programming paradigms. The list of topics in this course include: History & overview; Relevant software design tools; Software standards & constraints; Programming constructs & paradigms; Problem solving strategies; Software testing & quality assurance. Upon completion of this course, students should be able to: 1) Evaluate and apply programming paradigms and languages to solve a wide variety of software design problems, 2) Judge between software design trade-offs including maintainability, efficiency, and intellectual property constraints, 3) Design software test plans for evaluating a wide variety of performance criteria on subsystems (including usability, correctness, graceful failure, and efficiency), 4) Develop solutions by accounting diverse hardware-software contexts (i.e. platforms), 5) Create software design documentation that communicate effectively to software design stakeholders such as analysts, implementers, test planners, or maintainers, 6)Produce a high-level design of specific subsystems that is understandable to the stakeholders.

Prerequisite(s): Previous knowledge in programming, algorithms and data structures.

User Experience Design (7ECTS)

The purpose of this course is to teach students about the techniques and tools for user experience design for systems that are created for use in diverse domains of applications. The list of topics to be taught in this course include: Design tools and techniques; Integrative design; Application design; Stakeholder needs; Benchmarks and standards. Upon completion of this course, students should be able to: 1) Design interactive applications by applying user-centered design cycles and related tools and techniques, 2) Analyze and evaluate the context of software use, stakeholder needs, and state-of-the-art interaction modalities, 3)

Evaluate criteria for user experience design and the related compliance to the relevant standards, 4) Rate knowledge from related disciplines including human information processing, anthropology and ethnography, and ergonomics/human factors, 5) Make reflections for a service domain related to several disciplines in an interdisciplinary design team.

Prerequisite(s): None.

Information technology

1. Computer Networks (7ECTS)
2. Virtual Systems and Services (7ECTS)
3. Integrated Systems Technology (7ECTS)
4. Platform Technologies (7ECTS)
5. Platform-Based Development (7ECTS)

Computer Networks (7ECTS)

The purpose of this course is to introduce students on how to select, design, deploy, integrate, and administer network and communication infrastructures in an organization. It includes fundamental concepts in the design and implementation of computer networks and their protocols. Also, it includes layered network architectures, applications, transport, congestion, routing, data link protocols, local area networks. An emphasis is on the protocols used on the internet. A top-down approach is emphasized during the course starting from the application layer down to the data link layer. Upon completion of this course, students should be able to: 1) Develop, deploy, maintain, and evaluate the performance of wireless and wired networking solutions in the context of relevant standards and the needs of stakeholder groups and demonstrating awareness of the field. 2) Appraise, criticize, defend and/or judge general networking solutions while considering security and privacy aspects and the impact of solutions on citizens and society.

Prerequisite(s): Previous basic knowledge in computer communications and networks.

Virtual Systems and Services (7ECTS)

The purpose of this course is to introduce students to virtualization and its related open source components, deployment skills to build virtualization and clustered solutions as well as networked storage for virtualization infrastructure needs. Upon completion of this course, students should be able to: 1) Contrast virtualized and non-virtualized platforms. 2) Plan virtualization for applications, desktops, servers, and network platforms. 3) Design and develop a storage environment and prioritize performance measurement tools.

Prerequisite(s): Previous basic knowledge in computer networks and operating systems.

Integrated Systems Technology (7ECTS)

The purpose of this course is to introduce students to scripting languages, their uses and architectures, application programming interfaces and programming practices to facilitate the management, integration and security of the systems that support an organization. Upon completion of this course, students should be able to: 1) Judge how to code and store characters, images and other forms of data in computers and defend why data conversion is often a necessity when merging disparate computing systems together. 2) Appraise how a commonly used intersystem communication protocol works, including its advantages and disadvantages. 3) Design and develop a script that includes selection, repetition and parameter passing. 4) Judge the goals of secure coding, and plan how to use these goals as guideposts in dealing with preventing buffer overflow, wrapper code, and securing method access.

Prerequisite(s): Previous basic knowledge in computer networks and security.

Platform Technologies (7ECTS)

The purpose of this course is to introduce students to various operating systems available, including their respective characteristics, advantages and disadvantages, selection, deployment, integration and administration of platforms or components to support the organization's IT infrastructure and fundamentals of hardware and software and how they integrate to form the essential components of IT systems. Upon completion of this course, students should be able to: 1) Defend how the historical development of hardware and operating system computing platforms produced the computing systems we have today. 2) Grade the choices among operating system options 3) Judge the need for power and heat budgets within an IT environment, and grade the factors needed when considering power and heat in a computing system. 4) Develop a block diagram, including interconnections, of the main parts of a computer, and illustrate methods used on a computer for storing and retrieving data.

Prerequisite(s): Previous basic knowledge in computer architecture and operating systems.

Platform-Based Development (7ECTS)

The purpose of this course is to introduce students to the design and development of software applications that reside on specific software platforms. In contrast to general purpose programming, platform-based development takes into account platform-specific constraints. For instance web programming, multimedia development, mobile computing, app development, and robotics are examples of relevant platforms which provide specific services/APIs/hardware which constrain development. Such platforms are characterized by the use of specialized APIs, distinct delivery/update mechanisms, and being abstracted away from the machine level. Platform-based development may be applied over a wide breadth of ecosystems. Upon completion of this course, students should be able to: 1) Design for a client a responsive web application utilizing a web framework and presentation technologies in support of a diverse online community. 2) Develop a mobile app for a company that is usable, efficient, and secure on more than one device. 3) Simulate for a company an industry platform. 4) Develop and implement programming tasks via platform-specific APIs and present the results to a group of peers. 5) Develop an analysis of a mobile industrial system and illustrate correct security vulnerabilities.

Prerequisite(s): Previous basic knowledge in programming.

Information systems

1. Data and Information Management (7ECTS)
2. Systems Analysis & Design (7ECTS)
3. Computing Systems Fundamentals (7ECTS)
4. Project Management (7ECTS)
5. Enterprise Architecture (7ECTS)
6. IS Management and Leadership (7ECTS)
7. Social Issues and Professional Practice(7ECTS)

Data and Information Management (7ECTS)

The purpose of this course is to introduce students to important concepts in data and information management. It is centered around the core skills of identifying organizational information requirements, modeling them using conceptual data modeling techniques, converting the conceptual data models into relational data models and verifying its structural characteristics with normalization techniques, and implementing and utilizing a relational database using an industrial-strength database management system. The course will also include coverage of database administration tasks and key concepts of data quality and data security. In addition to developing database applications, the course helps the students understand how large-scale packaged systems are highly dependent on the use of DBMSs. Building on the transactional database understanding, the course provides an introduction to data and information management technologies that provide decision support capabilities under the broad business intelligence umbrella. Upon completion of this course, students should be able to: 1) Judge the role of databases and database management systems in managing organizational data and information. 2) Illustrate the difference between on-line transaction processing (OLTP) and online analytical processing (OLAP), and the relationship between these concepts and business intelligence, data warehousing and data mining. 3) Design a relational database so that it is at least in 3NF. 4) Evaluate data and information management technology alternatives for a small organization and suggest to management the most appropriate options based on the organizational information needs.

Prerequisite(s): Previous basic knowledge in databases.

Systems Analysis & Design (7ECTS)

The purpose of this course is to introduce students to the processes, methods, techniques and tools that organizations use to determine how they should conduct their business, with a particular focus on how computer-based technologies can most effectively contribute to the way business is organized. The course covers a systematic methodology for analyzing a business problem or opportunity, determining what role, if any, computer-based technologies can play in addressing the business need, articulating business requirements for the technology solution, specifying alternative approaches to acquiring the technology capabilities needed to address the business requirements, and specifying the requirements for the information systems solution in particular, in-house development, development from third-party providers, or purchased commercial-off-the-shelf (COTS) packages. Upon completion of this course, students should be able to: 1) Evaluate the types of business needs that can be addressed using information technology-based solutions. 2) Collaborate with various organizational stakeholders to collect information using a variety of techniques and to convey proposed solution characteristics to them. 3) Design high-level logical system characteristics (user interface design, design of data and information

requirements). 4) Judge and articulate ethical, cultural, and legal issues and their feasibility among alternative solutions.

Prerequisite(s): Previous basic knowledge in databases.

Computing Systems Fundamentals (7ECTS)

The purpose of this course is to provide a programmer's view on how a computer system executes programs, manipulates data and communicates. It enables students to become effective programmers in dealing with issues of performance, portability, and robustness. It provides an introduction to the systems-level view of computing, number representation, machine-level programming, representing high-level programs in machine code, memory, input/output, system architectures, operating systems, networks, parallelism/concurrency, communication/synchronisation. Upon completion of this course, students should be able to: 1) Analyze various basic hardware and software components that support the most fundamental operations of computers. 2) Evaluate the functions and operations of individual system software components including assemblers, compilers, linkers, loaders and operating systems. 3) Design system hardware components to meet specified operation requirements.

Prerequisite(s): None.

Project Management (7ECTS)

The purpose of this course is to introduce students to the processes, methods, techniques and tools that organizations use to manage their information systems projects. The course covers a systematic methodology for initiating, planning, executing, controlling, and closing projects. This course assumes that project management in the modern organization is a complex team-based activity, where various types of technologies (including project management software as well as software to support group collaboration) are an inherent part of the project management process. This course also acknowledges that project management involves both the use of resources from within the firm, as well as contracted from outside the organization. Upon completion of this course, students should be able to: 1) Evaluate the principal elements of management for a small project team. 2) Role-play the managerial aspects of a small project team, including software estimation, project planning, tracking, staffing resource allocation, and risk management. 3) Develop and implement plans for the measurement of software processes and work products using appropriate methods and tools. 4) Collaborate effectively with other team members in project management activities.

Prerequisite(s): None.

Enterprise Architecture (7ECTS)

The purpose of this course is to introduce students to the design, selection, implementation and management of enterprise IT solutions. The focus is on applications and infrastructure and their fit with the business. Students learn frameworks and strategies for infrastructure management, system administration, data/information architecture, content management, distributed computing, middleware, legacy system integration, system consolidation, software selection, total cost of ownership calculation, IT

investment analysis, and emerging technologies. These topics are addressed both within and beyond the organization, with attention paid to managing risk and security within audit and compliance standards. Students also hone their ability to communicate technology architecture strategies concisely to a general business audience. Upon completion of this course, students should be able to: 1) Evaluate a variety of frameworks for enterprise architecture analysis and decision making. 2) Evaluate the total cost of ownership and return on investment for architecture alternatives. 3) Grade techniques for assessing and managing risk across the portfolio of the enterprise. 4. Evaluate and plan for the integration of emerging technologies.

Prerequisite(s): None.

IS Management and Leadership (7ECTS)

The purpose of this course is to introduce students to the capability to develop, maintain, and consistently improve domain performance while providing appropriate information systems, services, and infrastructure. The capability focuses externally on creating value for the domain and internally on IS staff motivation, performance, and accountability. Upon completion of this course, students should be able to: 1) Apply professional management skills to the design and management of an effective IS organization. 2) Ensure operational efficiency and effectiveness in service delivery. 3) Govern IS project management principles and support their use in the organization. 4) Manage information systems use. 5) Manage information resources together with line management.

Prerequisite(s): Previous basic knowledge in project management.

Social Issues and Professional Practice (7ECTS)

The purpose of this course is to introduce important considerations relating to ethical and professional issues. It introduces students to ethical issues such as property rights, freedom of expression and privacy, and concepts such as free and open source software, ICT for Development, and Professional Codes of Conduct. It also equips students with tools for critical reasoning in order to construct and analyse ICT policy arguments and evaluate the ethical components in ICT case studies. Upon completion of this course, students should be able to: 1) Perform a system analysis for a local organization and present the results to them in a non-technical way. 2) Integrate interdisciplinary knowledge to develop a program for a local organization. 3) Document industry trends, innovations, and new technologies and produce a report to influence a targeted workspace. 4) Present to a group of professionals an innovative computer system by using audience-specific language and examples to illustrate the group's needs. 5) Produce a document that is helpful to others that addresses the effect of societal change due to technology. 6) Adopt processes to track customer requests, needs, and satisfaction. 7) Compare different error detection and correction methods for their data overhead, implementation complexity, and relative execution time for encoding, detecting, and correcting errors and ensure that any error does not affect humans adversely.

Prerequisite(s): None.

Data science

1. Data Acquirement and Governance (7ECTS)
2. Data management, Storage, and Retrieval (7ECTS)
3. Data Privacy, Security, and Integrity (7ECTS)
4. Machine learning (7ECTS)
5. Data Mining (7ECTS)
6. Big Data (7ECTS)
7. Analysis and Presentation (7ECTS)
8. Professionalism (7ECTS)

Data Acquirement and Governance (7ECTS)

The purpose of this course is to introduce the students to the usage and governance of the data. The specific topics include collecting data from different sources, annotating the data, auditing the data, availability of the data, usability, integrity and security of the data. Upon completion of this course, students should be able to: 1) Plan data collection from different sources, either ready available or open sources or third party data, 2) Appraise the data annotation and evaluate the accuracy and unbiased, 3) Reframe data to be available and accessible to those that need it but also ensuring consistently of the data and 4) Prioritize data security by ensuring the proper usage and limit corruption.

Prerequisite(s): Previous knowledge in programming and in databases.

Data management, Storage, and Retrieval (7ECTS)

The purpose of this course is to introduce students to fundamentals of database systems and approaches for further usage and manipulation with those systems. More specifically the topics will include storing and indexing different kinds of data, data models, query languages, database architectures, data retrieval and queries, processing transactions on databases and scaling of database systems. Upon completion of this course, students should be able to: 1) Design data management according to data types, models and architectures, 2) Design structure for efficient querying of the database systems, 3) Optimize the storage structure and query processing in data management systems for scalability and efficiency issues, 4) Plan a strategy for transaction processing to balance efficiency, scalability and consistency of data management systems, especially for parallel and distributed environments, and 5) Develop scalable and efficient algorithms for query processing, query optimization, transaction processing as well as information retrieval.

Prerequisite(s): Previous knowledge on databases.

Data Privacy, Security, and Integrity (7ECTS)

The purpose of this course is to introduce students to data privacy and its challenges, protection of data and soundness, completeness, accuracy and consistency of data. More specific topics will include trade offs on security and privacy, safeguarding of the data privacy, privacy requirements of organizations, people and government, basics of cryptography, mathematical concepts for encryption, symmetric and asymmetric ciphers, accuracy and consistency of data. Upon completion of this course, students should be able to: 1) Evaluate the concepts of privacy, 2) Judge privacy rights of individuals and society, 3) Safeguarding data privacy evaluation, 4) Prioritize cryptographic tools and concepts, 5) Develop methods for data privacy and security, 6) Value digital signatures and authenticated encryption but also other techniques for data integrity.

Prerequisite(s): Previous knowledge on programming and computer security.

Machine learning (7ECTS)

The purpose of this course is to introduce students to algorithms and techniques for data patterns, new inferences from data and also improving performance of systems related to data. More specifically, topics that will be covered are machine learning approaches, algorithms and tools, computational learning theories and limitations, problems related to data models, evaluation of the performance, evaluation of the models, different models, algorithms bias and data integrity. Upon completion of this course, students should be able to: 1) Prioritize learning approaches, 2) Judge different machine learning tools, 3) Plan an appropriate performance metric for evaluating machine learning algorithms, 4) Create machine learning programs from their algorithmic specifications, 5) Judge differences between models and 6) Evaluate problems related to data and algorithms.

Prerequisite(s): Previous knowledge on programming and statistics as well as a course on data management, privacy and security.

Data Mining (7ECTS)

The purpose of this course is to introduce students to the concept of applying machine learning and statistical approaches to get information from data. Some of the topics to be covered are: data mining workflow and its relation to data preparation and management, data mining models, design and analysis of data mining applications. Upon completion of this course, students should be able to: 1) Compose data mining models, 2) Design data mining systems, architecture and flow, 3) Develop efficient data mining algorithms and 4) Evaluate the results from the data mining models.

Prerequisite(s): Previous knowledge on programming and statistics as well as a course on data management, privacy and security and machine learning.

Big Data (7ECTS)

The purpose of this course is to introduce students to store vast amounts of data, ascertain that the data are of high quality, process those data efficiently and derive insightful results. Specific topics to be covered are: storing vast quantities of data, protecting data, ensuring that the data are clean, computational complexity related to big data, selecting appropriate algorithms, sampling and filtering of the data, concurrency and parallelism. Upon completion of this course, students should be able to: 1) Appraise the role of hierarchy when working with big data, 2) Evaluate the efficiency of the algorithms used, 3) Evaluate different approaches for filtering of the data and 4) Prioritize the limitations of concurrency / parallelism in dealing with problems of scale.

Prerequisite(s): Previous knowledge on programming and statistics as well as on data management, machine learning, data mining, distributed systems.

Analysis and Presentation (7ECTS)

The purpose of this course is to introduce the students to different approaches for animation, visualization and presentation of the data. Specific topics include: presenting data in written and graphical form, different visualization techniques for different data including time-varying data, spatial data, multivariate data, high dimensional multivariate data, tree- or graph-structured data and human computer interface considerations for clients. Upon completion of this course, students should be able to: 1) Judge data and inferences made from data orally, in written form and graphically, 2) Modify tools to visualize data, while also applying

different data visualization techniques, 3) Develop a suitable visualization design and 4) Write and document an analysis of client needs.

Prerequisite(s): Previous basic knowledge in statistical analysis and presentation.

Professionalism (7ECTS)

The purpose of this course is to introduce students to behave professionally and take proactive steps while being ethical. More specifically, the topics will include competency, acquiring expertise, different forms of communications, team selection and dynamics of the teams. Upon completion of this course, students should be able to: 1) Appraise the steps that would typically have to be taken to extend competence, 2) Evaluate the aspects of the technical literature, 3) Value the qualities desirable in the team and 4) Write and justify the considerations involved in selecting a team.

Prerequisite(s): None.

Cybersecurity

1. Data security (7ECTS)
2. Software security (7ECTS)
3. Web/Component security (7ECTS)
4. System security (7ECTS)
5. Human, organizational, and societal security aspects (7ECTS)

Data security (7ECTS)

The purpose of this course is to introduce students to key basic cryptography concepts, digital forensics, end-to-end secure communications, data integrity and authentication, and information storage security. Upon completion of this course, students should be able to: 1) Prioritize the most important key security requirements that are required for any security systems generally and specifically. 2) Develop code using encryption algorithms that are required to achieve confidentiality key security. 3) Design an appropriate encrypting system for a specific key size and message length. 4) Evaluate the suitability of a hash function for verifying the message integrity and digital signature authentication. 5) Appraise the role of distributed symmetric key in improving the asymmetric encryption systems.

Prerequisite(s): Previous basic knowledge in encryption, linear algebra and discrete mathematics.

Software security (7ECTS)

The purpose of this course is to introduce students to design principles including least privilege, open design and abstraction, security requirements and their role in design, implementation issues, static and dynamic testing, configuring and patching, and ethics, especially in development, testing and vulnerability disclosure. Upon completion of this course, students should be able to: 1) Grade the project's selected security lifecycle model (e.g., Microsoft SDL). 2) Identify security requirements by applying the selected security requirements method, 3) Incorporate security requirements into architecture, high-level, and detailed design. 4) Develop software using secure coding standards. 5) Execute test cases that are specific to security. 6) Adhere to the project's software development process, as a contributing member of a software project team. 7) Develop software that supports the project's quality goals and adheres to quality requirements.

Prerequisite(s): Previous basic knowledge of a high-level programming language

Web/Component security (7ECTS)

The purpose of this course is to introduce students to the design, procurement, testing, analysis and maintenance of components integrated into larger systems with a special focus on the web. The security of a system depends, in part, on the security of its components. The security of a component depends on how it is designed, fabricated, procured, tested, connected to other components, used and maintained. This knowledge area is primarily concerned with the security aspects of the design, fabrication, procurement, testing and analysis of components. Upon completion of this course, students should be able to: 1) Analyze how the security of a system's components might impact the security of the system. 2) Evaluate techniques for testing security properties of a component. 3) Analyze the difference between static and dynamic analysis in reverse engineering software. 4) Appraise ways to learn information regarding a component's functionality with limited information about its design and implementation.

Prerequisite(s): Previous basic knowledge in component programming.

System security (7ECTS)

The purpose of this course is to introduce students to the security aspects of systems that are composed of components and connections, and use software. Understanding the security of a system requires viewing it not only as a set of components and connections, but also as a complete unit in and of itself. This requires a holistic view of the system. System Security addresses the security issues of connecting components and using them within larger systems. Upon completion of this course, students should be able to: 1) Value the importance of a security policy. 2) Defend the value of a penetration test. 3) Appraise the importance of resilience in a specific environment. 4) Design a basic disaster recovery plan. 5) Defend why backups pose a potential security risk.

Prerequisite(s): Previous basic knowledge in component programming.

Human, organizational, and societal security aspects (7ECTS)

The purpose of this course is to introduce students to the tools and techniques used to identify flaws in environments that are vulnerable to social engineering attacks. Students taking this course will note common tools and techniques that will enable them to prepare responses and countermeasures within their organizations. The course covers the principles of persuasion and the psychological foundations required to craft effective attacks. It then bolsters that information with numerous examples of what works, drawing on the experiences of both cyber criminals as well as the course authors. Students will learn how to perform recon on targets using a wide variety of sites and tools, create and track phishing campaigns, and develop media payloads that effectively demonstrate compromise scenarios. Upon completion of this course, students should be able to: 1) Analyze psychological underpinnings of social engineering. 2) Design a social engineering test in your environment. 3) Develop new variations of attacks. 4) Evaluate ethical and risk challenges associated with social engineering engagements. 5) Modify penetration testing disciplines by understanding human behavior and how to exploit it.

Prerequisite(s): Previous basic knowledge in networks and security.

Methodology

The first draft of the list of courses was presented and discussed in the workshop organised on 28th of September 2021 by UP who are leading the Working Package 2. Within the DI-PhDICTKES project, the workshop is planned under the activity with the name "WP 2.3.2 Designing the courses that are required for the first year of PhD studies 60 ECTS PhD courses in Pristina".

In this workshop, 18 attendees from all 6 consortium partner Universities (UBT, University of Prishtina, University of Prizren, Norwegian University of Science and Technology, Linnaeus University and South East European Center) with the objective to create a deliverable about the syllabuses of the courses that are required for the PhD study program in ICT. In the group work session of the workshop, four different groups were created and assigned with a task of outlining the main learning outcomes of the program along

with the respective courses and their content. All of the participants are presented with an initial draft of the course syllabus, which could be commented and refined within a period of two months, as agreed among the participants.

Group name	**Participants**	
GROUP 1	• Anita Mirijamsdotir, LNU • Arianit Kurti, LNU • Kadri Sylejmani, UP • Krenare Pireva, UBT • Arsim Susuri, UPZ	
GROUP 2	• Eliot Bytyçi, UP • Petros Kefalas, SEERC • Sule Yildrim, NTNU • Jorida Xhafaj, UBT	
GROUP 3	• Ermir Rogova, UP • Zenun Kastrati, LNU • Ercan Canhasi, UPZ • Mohamed Abomhara, NTNU • Edmond Jajaga, UBT	
GROUP 4	• Yannis Spyridis, SEERC • Ali Shariq Imran, NTNU • Päivi Jokela, LNU • Ermira, UPZ	